Technical Overview for Science Case Subcommittees

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Presentation Sequence

- AOWG Strategic Plan
- KPAO Requirements & Performance
- Science Instruments
- Future AO Capabilities (building on KPAO)
- The Competitive Landscape
Keck NGAO

AOWG Strategic Planning

- Proposed timeline defined at 11/02 Strategic Planning (SP) meeting.
  - K1 laser added in early 03
- Priorities confirmed at 9/04 SP meeting.
- Mike Brown: “AOWG vision is that high Strehl, single-object, AO will be the most important competitive point for Keck AO in the next decade.”
  - Based on science cases presented/discussed by AOWG members
  - Top-level requirements defined by a subgroup & approved by AOWG
## KPAO - Requirements

### KPAO High-level Performance Requirements Summary:  
(based on AOWG 11/12/02 strategic plan report & KAON 237)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Requirement</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>High IR Strehl ratios</td>
<td>rms wavefront error = 120 or 180 nm (cases to be evaluated)</td>
<td>On-axis (LGS &amp; NGS) case under median seeing conditions, &lt; 45° zenith angle, NGS V &lt; 17 mag. Includes atmospheric, telescope, AO &amp; science instrument contributions.</td>
</tr>
<tr>
<td>High Strehl stability</td>
<td>rms wavefront error maintained to ± 15 nm</td>
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</tbody>
</table>
| Moderate field of view    | Science: 60”  
WF sensor: 60”  
TT sensor: 120”                                                                  | Diameter.                                                                                                                            |
|                            |                                                                             | For sensing this is field of regard.                                                                                                 |
| Sky coverage               | Near complete                                                               |                                                                                                                                      |
| PSF                        | Good knowledge                                                              | Requires well calibrated real-time diagnostics                                                                                         |
| Wavelength coverage       | Science: 0.45 to 14 μm                                                      |                                                                                                                                      |
| Class                      | Facility-class                                                               |                                                                                                                                      |

Keck NGAO

Keck AO and KPAO compared

Simulation of AO systems
V=14 natural guide star, 2.1 microns (K band)

Natural Guide Star
FWHM 53 mas
Strehl 0.19

Laser Guide Star
FWHM 47 mas
Strehl 0.36

KPAO
FWHM 46 mas
Strehl 0.89
Keck NGAO

KPAO Strehl vs. rms wavefront error

Hα  J  H  K

KPAO Baseline
120 nm

- 90 nm
- 120 nm
- 180 nm
- NGS 250 nm
- LGO 400 nm

Wavelength (nm)

Strehl
KPAO: Predicted Performance

Hα Strehl ~0.2
Resolution 4x HST
& collection gain
16x HST

J-band Strehl ~0.6
Comparable to current AO at K
with ~2x resolution

K-band Strehl ~0.85
Highest contrast
Best separation in crowded fields
Keck NGAO

KPAO: Key Predicted Parameters

- ~ 1300 actuators (40x40 subapertures)
- 1500 Hz bandwidth
- 7x 20W lasers
- 1 e- wavefront sensor read noise
- Partial correction of NGS needed to achieve reasonable sky coverage (IR tip/tilt sensor; partial MCAO?)
Science Instruments

- Not yet defined
- Some ideas
  - Start with OSIRIS
  - Rebuild NIRC2 to higher wavefront quality
  - Larger field IR Integral Field Spectrograph
  - Visible imager
  - Visible Integral Field Spectrograph
- Interferometer: Must still AO correct both telescopes
Potential Synergy between KPAO & Future AO Capabilities

KPAO
High IR Strehl
Narrow FOV
Visible Capability

KPAO measures turbulence using multiple LGS & tomography

Wide-field AO can use these measurements to correct atmosphere

Multi-Conjugate AO
High IR Strehl
Moderate IR Strehl
~ 2' FOV
Multiple DMs

Multi-Object AO
High IR Strehl
~ 7' FOR
AO postage stamps (MEMs) within FOR

KPAO
High visible Strehl
Narrow FOV
## Keck NGAO: The Competitive Landscape

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Telescope</th>
<th>Capabilities</th>
<th>Dates</th>
<th>Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>WFPC2</td>
<td>HST</td>
<td></td>
<td>-2010</td>
<td>Operation</td>
</tr>
<tr>
<td>Keck II LGS with NIRCam &amp; OSIRIS</td>
<td>Keck II</td>
<td>SR = 30-40% at K, SR = 10% @ K (R = 19)</td>
<td>2004-</td>
<td>Operation</td>
</tr>
<tr>
<td>Altair with LGS</td>
<td>Gemini-N</td>
<td></td>
<td>2006-</td>
<td>Telescope I&amp;T</td>
</tr>
<tr>
<td>NACO with LGS</td>
<td>VLT</td>
<td></td>
<td>2006-</td>
<td>Telescope I&amp;T</td>
</tr>
<tr>
<td>LGS AO</td>
<td>Palomar</td>
<td></td>
<td>2006-</td>
<td>Telescope I&amp;T</td>
</tr>
<tr>
<td>Laser (Rayleigh) Tomography AO</td>
<td>MMT</td>
<td></td>
<td>2006-</td>
<td>Telescope I&amp;T</td>
</tr>
<tr>
<td>Coronagraphic Imager (CIAO) LGS AO</td>
<td>Subaru</td>
<td>188-act curvature, 4W SF laser SR = 0.56 at K (V = 10) 1kx1k InSb (11.22 mas/pix)</td>
<td>2007-</td>
<td>Development</td>
</tr>
<tr>
<td>MCAO</td>
<td>Gemini-S</td>
<td>2’ science field</td>
<td>2007-</td>
<td>Development</td>
</tr>
<tr>
<td>Keck I LGS with OSIRIS</td>
<td>Keck I</td>
<td>20W laser, center projection</td>
<td>2008-</td>
<td>SDR</td>
</tr>
<tr>
<td>Adaptive Secondary + Pyramid WFS</td>
<td>LBT</td>
<td></td>
<td>2008-</td>
<td>Development</td>
</tr>
<tr>
<td>GTC A O LGS upgrade</td>
<td>GTC</td>
<td></td>
<td>2008-</td>
<td>Concept</td>
</tr>
<tr>
<td>LGS Multi Unit Spectrograph Explorer</td>
<td>VLT</td>
<td>SR ~ 10% in visible, 5-10” fov</td>
<td>2008-</td>
<td>Final design</td>
</tr>
<tr>
<td>PALM-3000 + Oxford SWIFT</td>
<td>Palomar</td>
<td>149 nm wfe LGS, 98 nm wfe NGS, red optimized 44x89 IFU</td>
<td>2009-</td>
<td>Proposal</td>
</tr>
<tr>
<td>Planet Imager (GPI)</td>
<td>Gemini-S</td>
<td></td>
<td>2010-</td>
<td>Prelim Design</td>
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<tr>
<td>Adaptive Secondary</td>
<td>VLT</td>
<td></td>
<td>2010-</td>
<td>Prelim Design</td>
</tr>
<tr>
<td>Four LGS Facility (LGSF4)</td>
<td>VLT</td>
<td></td>
<td>2010-</td>
<td>Approval?</td>
</tr>
<tr>
<td>Planet Finder</td>
<td>VLT</td>
<td></td>
<td></td>
<td>Study</td>
</tr>
<tr>
<td>Multi-seeing reducer (FALCON)</td>
<td>VLT</td>
<td>Deployable mini-IFUs with MEMS, near IR, 20-30’ FoR</td>
<td></td>
<td>Study</td>
</tr>
<tr>
<td>Next Generation Keck AO</td>
<td>Keck II</td>
<td></td>
<td>2012-</td>
<td>Study</td>
</tr>
<tr>
<td>Visible All Sky AO (VASAO)</td>
<td>CFHT</td>
<td>&gt;0.6μm diff-limit &lt;0.6nm 50mas</td>
<td>2012-</td>
<td>CoDR</td>
</tr>
<tr>
<td>NIRCam</td>
<td>JWST</td>
<td>&lt;0.1” images, 0.6-5 μm, 2.3x2.3’ field</td>
<td>2014-</td>
<td>Design</td>
</tr>
<tr>
<td>NIRSpect</td>
<td>JWST</td>
<td>100 objects, 1-5 μm, 3x3’ field</td>
<td>2014-</td>
<td>Design</td>
</tr>
<tr>
<td>IRIS (IR Imaging Spectrometer) with NFIRAOS (Narrow Field IR AO System)</td>
<td>TMT</td>
<td>1-2.5 μm, R~4000 1st light: 199nm rms (r0=15cm) Upgrade: 169nm rms</td>
<td>2015-</td>
<td>Feasibility</td>
</tr>
<tr>
<td>IRMOS</td>
<td>TMT</td>
<td>0.8-2.5 μm, R~2000-10000 50% EE in 50mas, N=16 multiplex, FoR = 5’, full sky coverage</td>
<td>2016-</td>
<td>Feasibility</td>
</tr>
<tr>
<td>PFI (Planet Formation Instrument)</td>
<td>TMT</td>
<td>1-2.5 μm, 10^8 contrast</td>
<td>2015-</td>
<td>Feasibility</td>
</tr>
<tr>
<td>NIRES (Echelle Spectrometer) &amp; WIRC (Wide-field Infrared Camera) with NFIRAOS</td>
<td>TMT</td>
<td></td>
<td>2019-</td>
<td>Concept</td>
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